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Poster Session 2

Kentucky Water Resources Research Institute, University of Kentucky

POSTER SESSION 2

1. KENTUCKY LAKE UNDERGOING A "CHANGE OF STATE": TREND ANALYSES INDICATE POTENTIAL TIPPING POINTS ARE BEING REACHED FOR SEVERAL LIMNOLOGICAL VARIABLES

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The Kentucky Lake Long-term Monitoring Program (KLMP) was begun in July 1988 to understand the basic limnology of this very large Tennessee River reservoir and to document patterns and trends. A wide variety of biological, chemical, and physical measurements are taken every 16 days (32 days December – February) at 12-14 lake sites and several tributary sites. Trend analyses reveal important changes taking place in the lake over the past 30 years. Some variables appear to have reached "tipping points" resulting from changes in the watershed and/or from species invasions.

Mean water temperature has steadily increased by 2 °C over the 30-year period of record. Mean total alkalinity has increased from 50 to 60 mg $CaCO_3$/L (Fig. 1). Mean chloride ion concentration has doubled from 5 mg/L to 10 mg/L (Fig. 2). Secchi depth (Fig. 3) and 1% light penetration have increased by 0.5 meters and 2.5 meters, respectively. Silicon dioxide has increased 1.5 mg/L, and soluble reactive phosphate has increased 0.1 mg/L. Significant decreasing trends over 30 years include sulfate, down from 20.0 to 8.8 mg/L; turbidity down from 15 to 4 NTU's, primary production down from 40 to 30 µg C/L/h, and oxidation-reduction potential down from 0.3 to 0.2 mv. Dissolved organic carbon has decreased from 2.5 to 2.0 mg/L. Variables that have remained relative constant include chlorophyll-*a*, total nitrogen, and total phosphorus. Many of the changes in the variables discussed above were also driven by strong seasonal effects.

It is obvious that many of the decreases and increases result from synergistic relationships among the parameters particularly as they relate to changes in ecosystem processes and invasive species. While present in the Ohio River for more than 30 years, silver carp (*Hypophthalmichthys molitrix*) only recently has become a super invader in Kentucky Lake. Its long-term effects on the phytoplankton and zooplankton populations remain to be determined, but the decrease in primary production over the past several years is unmistakable even though chlorophyll-*a* has remained fairly constant.

Zebra mussels (*Dreissaena polymorpha*) had become established in the Ohio River basin by 1992. They were reported from the Tennessee River basin at the same time but only as occasional sightings. The lack of reproducing populations was attributed to Ca^{++} levels below the 21-23 mg/L threshold. Between 2012 and 2017, Ca^{++} levels increased from ~15 mg/L to above the threshold. Reproducing zebra mussel populations appeared for the first time in the spring of 2017. The source(s) of the Ca^{++} have yet to be determined but likely come from increased use of road deicing brine ($CaCl_2$) and from runoff and precipitation containing higher alkalinity ($CaCO_3$). As with silver carp, zebra mussels are voracious filter feeders. The effects of the combination of both species on the Kentucky Lake ecosystem will be quite interesting to see. Over the past few months, there has been a noticeable change in Secchi depth with visibility going from ~2 to over 4 m.

The KLMP database has detected several significant changes in water quality and biology over the past 30 years. Alterations in land use and the effects of invasive species appear to be the primary drivers. The trends appear to be irreversible and have led to a "change of state" for Kentucky Lake.

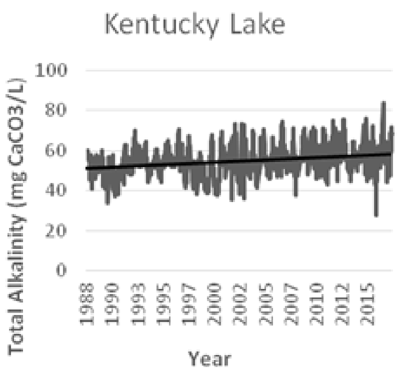

Fig. 1. Long-term total alkalinity trends

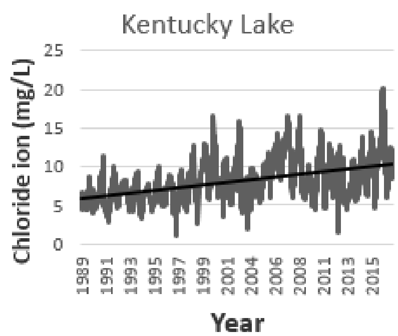

Fig. 2. Long-term chloride trends

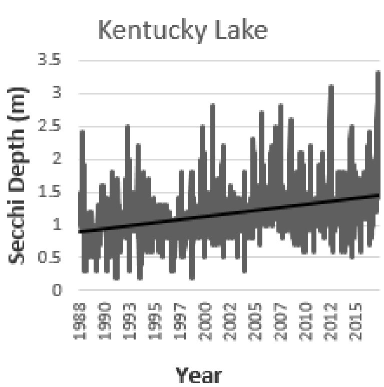

Fig. 3. Long-term Secchi depth trends

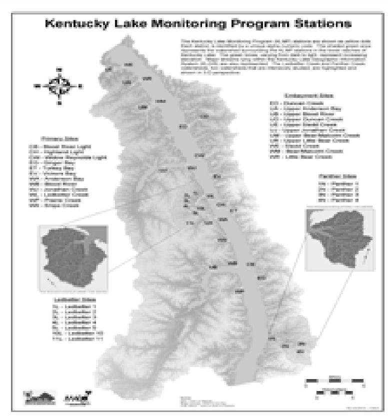

Fig. 4. KLMP watershed map

2. INVESTIGATING PREFERENTIAL SEWER PATHWAYS: GEOSPATIAL SCREENING AND FIELD SAMPLING TO REDUCE INHALATION EXPOSURE RISKS

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Hazardous waste sites are common across the United States (US). Superfund sites, generally regarded as the nation's worst hazardous waste sites, are found in every state and are managed by the federal government. While there are approximately 1,340 Superfund sites, in total there are more than 400,000 contaminated sites nationwide. For populations living close to these locations, exposure to contaminated environmental media, including groundwater, soil, and air, can lead to increased risk of adverse health effects. Vapor intrusion (VI) is one process by which nearby populations can be exposed to contaminants. A well-known issue at a significant portion of hazardous waste sites, VI refers to the migration of contaminant vapors from subsurface sources into indoor air environments.

Recent studies have shown that the existence of preferential transport pathways can complicate VI investigations and increase the geographic range and health risks associated with VI around hazardous waste sites. Sewers are preferential pathways of particular concern and are currently being investigated at many locations in the US and internationally. In the US, nearly one million miles of public sanitary sewer mains and half a million miles of private sanitary sewer laterals are buried in the subsurface. Many of these pipes have critical deficiencies that weaken a system's ability to operate optimally. Pipe deterioration over time allows infiltration of surface water and groundwater. Near contaminated sites, this can result in the migration of contaminated groundwater and vapors into the sewer system. Once in the sewer system, volatile organic compounds (VOCs) can migrate throughout the pipe network and infiltrate into connected buildings through non-vapor-tight plumbing connections. Researchers have shown that this unintentional entry of sewer gas can lead to contaminant concentrations in excess of protective, risk-based screening levels in indoor air.

The primary objective of this research project is to develop a screening-level method to identify critical characteristics of contaminated sites that highlight where additional evaluation of VI may (and may not) be necessary. Geospatial evaluation of sanitary sewers and hazardous waste sites is accomplished using spatial data and metadata available from city and regulatory databases. This analysis provides insight into which sites are likely to have elevated concentrations of hazardous contaminants in sewer gas and thereby increase exposure risks for populations living nearby.

Sites with groundwater contamination issues stemming from vapor-forming chemicals, such as petroleum hydrocarbons and chlorinated solvents, are more likely to have VI issues. Dry cleaning facilities are of particular concern because numerous petroleum-based and chlorinated solvents have been used historically for dry cleaning operations, and these facilities are often located within residential areas.

Four sites have been selected for further evaluation by field sampling. Figure 1 shows a map of one of the sites. The star denotes the location of a former dry cleaning facility. The lines and arrows symbolize the location of sanitary sewer mains and direction of sewage flow, respectively. The circles represent the locations of sanitary sewer manholes. Lastly, the diamonds indicate the locations of groundwater monitoring wells where "hot spots" of tetrachloroethylene and trichloroethylene (i.e., chlorinated dry cleaning solvents) have been detected above maximum contaminant levels.

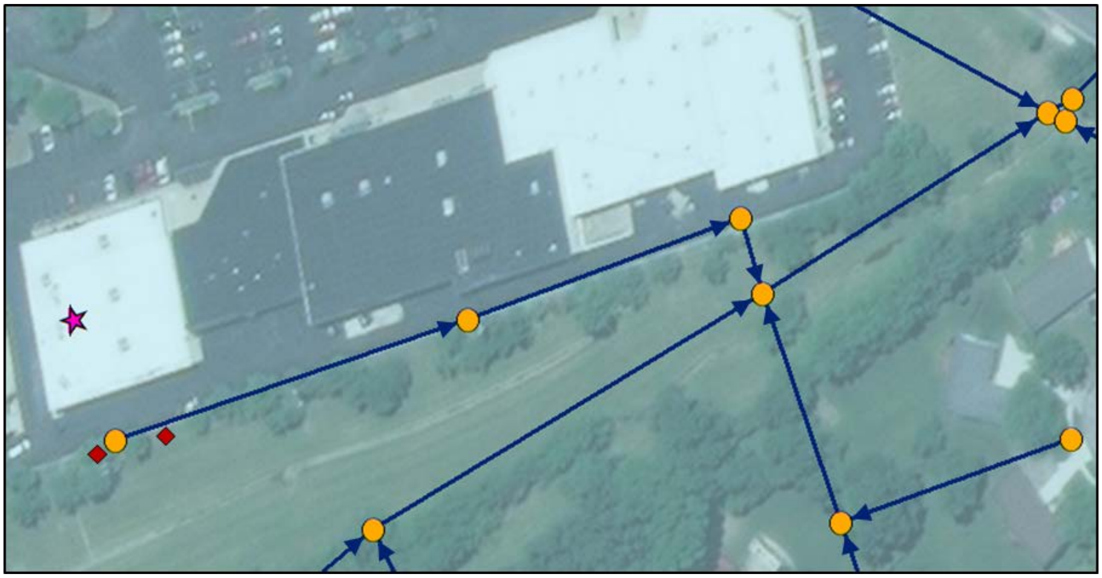

Figure 1: Site map showing locations of sanitary sewer mains, manholes, and contaminated groundwater hot spots

Preliminary screening indicates that sewer pipes adjacent to the selected study sites have great potential to be deteriorated and thus impacted by nearby contaminated groundwater and vapors. At each site, targeted sewer gas sampling of VOCs will occur at several sewer manholes, both close to and away from the known groundwater plumes. The results of this field study will complement the geospatial tool to improve screening criteria for identifying which sites have sewers that should be tested for VOCs. Considering the pervasiveness of hazardous waste sites and deteriorated wastewater infrastructure in the US, preferential sewer pathways may be fairly common. However, this tool could ultimately help determine which sewer systems are of greatest concern for this issue and should be selected for additional investigation or mitigation.

Acknowledgements: Reported findings were supported by the National Science Foundation (1452800), the Kentucky Water Resources Research Institute, and the National Institute of Environmental Health Sciences (University of Kentucky Superfund Research Program, P42ES007380). The content is solely the responsibility of the authors and does not necessarily represent the official views of any funding agency.

3. FATE AND TRANSPORT OF VOLATILE ORGANIC COMPOUNDS (VOCS) IN A SEWER SYSTEM: NUMERICAL MODEL AND FIELD STUDY

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Vapor intrusion refers to the migration of volatile organic compounds (VOCs) vapors from any subsurface source into the overlying buildings. Until recently, vapor intrusion had been described by the migration of VOC vapors through soil and their infiltration into the indoor area through foundation's cracks. Several vapor intrusion field studies have not been well-explained by this conceptual model. Evidence has established that VOCs vapors can use alternative pathways to enter into the buildings. Sewer systems are one alternative pathway that have been recognized as important by the US Environmental Protection Agency's (USEPA's) most recent vapor intrusion technical guidance (2015).

There is limited information available regarding the occurrence of VOCs inside the sewer systems and this pathway has not been well characterized to date. This research investigates VOCs concentration and its spatial and temporal variations inside a sewer line adjacent to and extending hundreds of feet away from a previously defined vapor intrusion area, through conducting a field study. A numerical model is developed to improve our understanding about the results of the field study and evaluate parameters that govern VOCs mass transport and could be responsible for the observed temporal/spatial fluctuations of VOC concentrations inside the sewer system.

The numerical model simulates VOCs different mass transfer mechanisms within the sewer systems and assesses the sewer gas VOC concentration on different scenarios. By comparing the results of the developed numerical model with data measured during the field study, this research aims to improve the numerical model considerations. Figure 1 shows the area assessed by the numerical model. Slope of the sewer line, sewer lines diameters, sewer flow direction, sewer flowrate and several other details are considered in the numerical model.

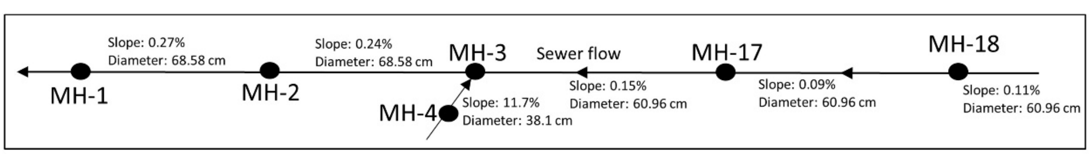

Figure 1: Sewer flow direction on the targeted Street.

The liquid gas mass transfer, vapor diffusion, adsorption and biodegradation are four major mass transfer mechanisms included in the proposed model effect of different parameters are investigated by considering various scenarios. Table 1 shows some of these scenarios. Figure 1 compares the results of these scenarios with measured TCE sewer gas concentrations conducted during the field study.

$$R_{total} = V.\frac{dc}{dt} = R_{in} - R_{out} + R_{liquid\text{-}gas} + R_{diffusion} + R_{adsorption} + R_{biodegradation}$$

Table 1. Descriptions of the cases plotted on Figure 2

Case 1	Close sewer system, no tributary from MH-4, no drop structure, no adsorption
Case 2	Open manhole , no tributary from MH-4, no drop structure, no adsorption
Case 3	Open manhole, depth at MH-4=0.1 m, no drop structure, no adsorption
Case 4	Open manhole, depth at MH-4=0.1 m, drop height=0.25 m, no adsorption
Case 5	Open manhole, depth at MH-4=0.1 m, drop height=0 m, adsorption (S_s = 250 (mg/L); S_d= 200 (mg/L))
Case 6	Open manhole, depth at MH-4=0.1 m, drop height=0.25 m, adsorption (Ss = 250 (mg/L); Sd= 200 (mg/L))

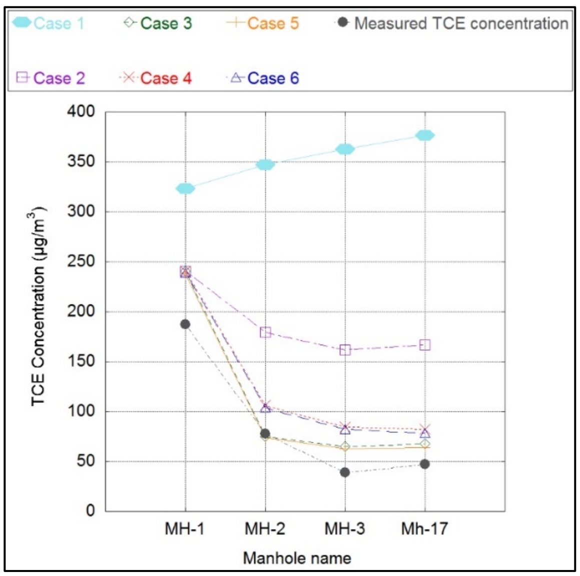

Figure 2. TCE measured concentration VS calculated concentration.

- Results of Case 1 and Case 2 do not match well with the field data; suggesting that the sewer line as a closed system with no tributary are not appropriate assumptions for this model.
- Case 3 and Case 5 match well with the filed data; suggesting that the scenarios with no drop structure are better matched with the results.
- Adsorption has a relatively slight effect on the sewer gas TCE concentration on these scenarios, but improves the model.

Acknowledgements: The project described was supported by a CAREER Award from the National Science Foundation (Award #1452800) and by Grant Number P42ES007380 (University of Kentucky Superfund Research Program) from the National Institute of Environmental Health Sciences. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute of Environmental Health Sciences, the National Institutes of Health or the National Science Foundation.

4. SOIL MOISTURE CONDITIONS AND YIELD ACROSS FRAGIC SOILS UNDER IRRIGATED MANAGEMENT IN WESTERN KENTUCKY

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There has been a significant increase (204 percent) in the number of high-yield (300 to 1,200 gal/min) agricultural irrigation wells installed in the northern portion of the Mississippi Embayment in western Kentucky since the drought of 2012. Because large scale irrigation is relatively new to Kentucky, little is known about irrigated row-crop management in the state. The objective of this study was: 1. To demonstrate the utility of off-the-shelf water management technology including soil moisture sensors and irrigation well flow meters to producers and; 2. To evaluate soil moisture and yield under irrigation during the corn growing season in soils common in western Kentucky. The study site was an irrigated agricultural field in Hickman County, Kentucky. The predominant soil under the center pivot, as mapped by USDA-NRCS, is a Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalf). These soils have a fragipan, which limits water infiltration, within 3 ft of the soil surface. The field has been in a no-till corn – soybean rotation for over 2 decades. Corn was grown at the time of this investigation. A flowmeter was installed between the well-head and irrigation pivot to quantify the amount of added water. In addition, groundwater elevation data were collected from the irrigation well by a pressure transducer. The soil moisture sensors (similar to gypsum blocks) measure soil moisture tension and were installed at 1, 2 and 3 ft depths within a row (between plants) at each of 7 locations under the center pivot and at 1 location outside the pivot. Data were collected every 30 minutes and transmitted from the field via cellular connection to a website where the data were posted. Corn yield estimates were made by hand harvesting 10 ft of plants from two rows adjacent to each soil moisture sensor array. Wet weather led to delays in side-dressing nitrogen which needed to be completed prior to equipment installation. Additionally, technical difficulties with the soil moisture sensor communication equipment caused us to miss one irrigation event and 2 rainfall events between May 10, 2017 (planting date) and July 18, 2017 (date of first soil moisture reading). As a result, data collection began at the late corn vegetative growth stages and continued through maturity.

It appears that climatic conditions were suitable for high yields in western Kentucky, with and without irrigation. Corn yield ranged from an average of 232 to 265 bu/A across the irrigated array locations; the dryland location yield averaged 262 bu/A. The similarity in yield between irrigated and dryland locations is probably due in part to the 11.4 inches of precipitation that fell between May 10 and Aug. 31 (maturity) occurred at critical growth stages required to attain high yields. At most array sites, soil moisture at 1 ft exhibited an increase with precipitation and irrigation events, but was unchanged at 2 ft and 3 ft. This suggests that the majority of soil moisture utilized for crop growth during our monitoring period was coming from the near surface.

Though the farm owner/operator appreciated the ability to monitor real-time soil moisture field conditions while away on a 7-day trip, the technical difficulties associated with setting up the system made him hesitant to employ this technology in the future. He instead prefers monitoring soil moisture conditions using a hand-held sensor, obtaining readings at select locations within the field. He was, however, pleased to see the relationship between data obtained with the hand-held sensor and that of the *in-situ* moisture sensors demonstrated with this study.

5. NUTRIENT CONTAMINATION FROM AN AGRICULTURAL NON-POINT SOURCE AND ITS MITIGATION: A CASE STUDY OF EKU MEADOWBROOK FARM, MADISON COUNTY, KY

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Non-point sources are now responsible for most nutrient contamination in surface water and groundwater, leading to eutrophication and decreased water quality. Because of fertilizer use and animal husbandry, agricultural areas are prime sources for nutrient contamination. Consequently, it is advisable to mitigate entry of nutrients into watersheds from agricultural runoff and groundwater flow. Eastern Kentucky University (EKU) Meadowbrook Farm (Madison County, Kentucky) seeks to decrease its export of nutrients to Muddy Creek, which is tributary of the Kentucky River. To demonstrate the efficacy of any sequestration strategies, nutrient export must be measured both before and after sequestration efforts are implemented.

Over the past two field seasons, we have investigated the sources and behavior of dissolved nutrients (phosphate, PO_4^{3-}; ammonium, NH_4^+; nitrate, NO_3^-) and other dissolved ions, and their transport via hydrologic pathways at the Farm. Here, we present our findings in three parts:

1) background nutrient concentration in surface water and groundwater during fair-weather times and identification of likely nutrient sources (Borowski et al.);
2) details of cation and nutrient drainage from the Farm during rain events (Buskirk et al.); and
3) quantification of nutrient export from a representative sub-watershed on the Farm during a major rainfall event (Winter et al.).

Meadowbrook Farm is a working farm raising crops (mainly corn and soybeans), and rearing dairy and beef cattle and other livestock. Livestock produce manure that is eventually applied to pasture and croplands; supplemental fertilizer is also used. These are the primary sources for excess nutrients that leave the Farm via overland and groundwater flow.

We sampled water from several different water sources and measured their nutrient content. Water types include that from drainage tiles, springs (groundwater), and surface water within intermittent streams on the Farm, other adjacent streams, and Muddy Creek. Water samples were passed through a 0.4 □m syringe filter and then preserved at a pH of 2 with sulfuric acid (H_2SO_4). Nutrient concentration, expressed in terms of phosphorus (P) and nitrogen (N) content, was measured colorimetrically using an UV-VIS spectrophotometer and the ascorbic acid (orthophosphate; P-PO_4^{3-}), sodium hypochlorite (ammonium, N-NH_4^+), and cadmium reduction (nitrate, N-NO_3^-) methods.

Nitrate is the nutrient contaminant with highest median concentration (~1.1 mg/L N-NO_3) in surface waters; median concentration for ammonium and phosphate are ~0.3 mg/L N-NH_4^+ and ~0.03 mg/L P-PO_4^{3-}, respectively. Relative to national data, Farm groundwater is enriched in all nutrients with median concentrations of ~0.04 mg/L N-NH_4^+, ~7.3 mg/L N-NO_3, and ~0.04 mg/L P-PO_4^{3-}. Enrichment in ammonium is more significant compared to that of nitrate and phosphate. These data provide fair-weather, background estimates for comparison to nutrient export that occur during rain events.

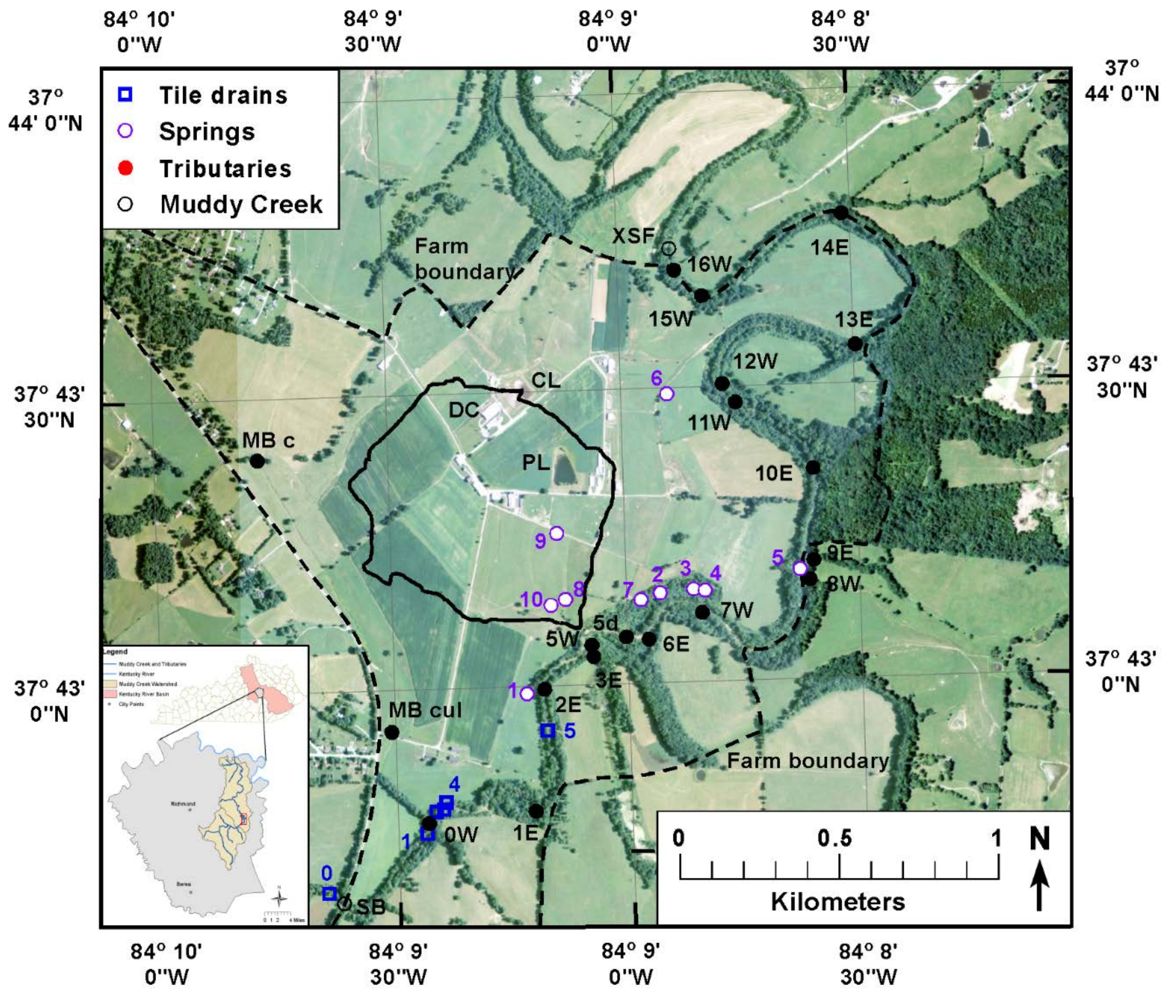

Figure 1. Map of EKU Meadowbrook Farm and sampling stations. The Farm (dashed outlined) is generally bounded by Muddy Creek on the east that flows from south to north. Symbols for sampling stations indicate water type. Note the black polygon that shows the BRC sub-watershed, which drains the cow (CL) and pig (PL) lagoons and the diary complex (DC), as well as pasture and cropland. The BRC flows through at instrumented weir at station 5W.

6. CHARACTERIZATION OF GROUNDWATER AND SURFACE WATER GEOCHEMISTRY IN AN AGRICULTURAL SETTING AT EKU MEADOWBROOK FARM, MADISON COUNTY, KENTUCKY

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Agricultural activities often contaminate watersheds with excess nutrients leading to poor water quality and eutrophication. Eastern Kentucky University (EKU) Meadowbrook Farm raises crops and livestock, which contribute dissolved nutrients to the neighboring Muddy Creek watershed. Consequently, the Farm is developing methods to sequester phosphorous and limit nutrient contamination.

Before phosphorous sequestration methods can be tested, Farm surface water and groundwater geochemistry must be better understood to determine hydrological pathways for nutrients. We use naturally-occurring dissolved cations, pH, oxidation-reduction potential (ORP), specific conductivity (SC), dissolved oxygen (DO%), total hardness, and alkalinity as chemical tracers to parse the contribution of dissolved ions from different water sources, to recognize different water source chemistries, and to interpret storm events. To measure discharge from a proximal, intermittent stream that drains a representative and critical portion of the Farm, we used an instrumented, V-notch weir to examine storm-water flow during Tropical Storm Cindy (June 22-25, 2017).

Water samples taken from springs (groundwater), surface water, and storm water on the Farm were analyzed for various dissolved constituents. Dissolved cations were measured via ICP-OES (ACT Labs) for sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}). pH, ORP, SC, and DO% were determined with YSI and Vernier probes. Alkalinity and total hardness were measured via the bromocresol green - methyl red and the EDTA digital titration methods, respectively. Dissolved ammonium (NH_4^+), nitrate (NO_3^-), and phosphate (PO_4^{3-}) concentrations were determined by colorimetry with a UV-VIS spectrophotometer via the sodium hypochlorite, cadmium reduction, and ascorbic acid methods, respectively.

Both groundwater and surface water sources exhibit similar ranges of pH (neutral to basic), ORP (oxidizing), alkalinity, total hardness, DO%, and SC. Source waters generally have high Ca^{2+} and Mg^{2+}, and low K^+, Na^+, PO_4^{3-}, and NH_4^+ concentrations. This strongly suggests that background chemistries of source groundwater and surface water are controlled by local limestone bedrock dissolution. Groundwater is further characterized by relatively high NO_3^- concentrations and low temperatures; in contrast, surface waters exhibit higher temperatures and lower NO_3^- concentrations.

During the Cindy event, concentration of Ca^{2+}, Mg^{2+}, and Na^+ within baseline source waters decreased with increasing discharge through the weir (Fig. 1), along with SPC, pH, and alkalinity. This behavior represents dilution of Farm groundwater by storm precipitation and subsequent overland flow. However, K^+ increased from baseline concentrations, spiking concurrently with increased discharge through the weir, and then progressively decreased in magnitude over the duration of the storm (Fig. 2). These data suggest that K^+ was flushed from soil by rain waters.

Nutrient concentrations increase with increased discharge indicating transport by surface runoff. For example, PO_4^{3-} concentrations closely track and are proportional to discharge, which suggests PO_4^{3-} transport from the surficial soil substrate via flushing by precipitation (Fig. 3). NO_3^- exhibited nearly identical transport behavior as K^+; concentration spikes occur simultaneously with K^+ and discharge. However, NO_3^- levels reached a higher baseline concentration than pre-storm levels. The Cindy event suggests infiltration and retention of NO_3^- within soil and groundwater during fair weather, initial flushing during the rain event, and then prolonged NO_3^- release from Farm soil and groundwater.

Background concentration of NH_4^+ is generally 0.0 to 0.2 mg/L. Immediately prior to water flow over the weir during the Cindy event, concentrations were unusually high (~1.7 mg/L). During the first storm pulse, these high concentrations decreased significantly to <0.4 mg/L. Later in the main storm event, NH_4^+ tracked discharge from the weir and afterward returned to typical background concentrations. This behavior suggests rapid release of NH_4^+ from soil followed by accumulation within the weir pool and then subsequent flushing during the precipitation event.

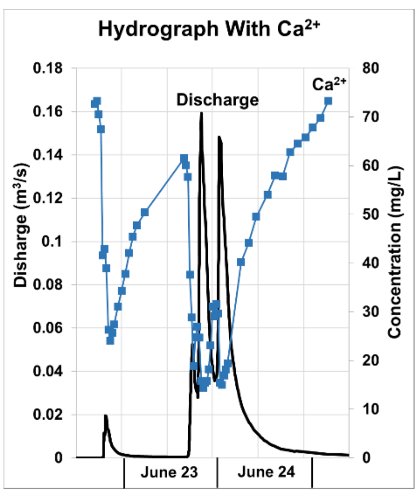

__Fig. 1.__ Discharge hydrograph and Ca^{2+} concentration during Tropical Storm Cindy.

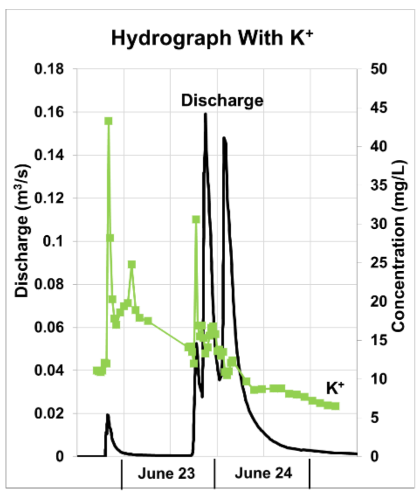

__Fig. 2.__ Discharge hydrogrpah and K+ concentration during Tropical Storm Cindy.

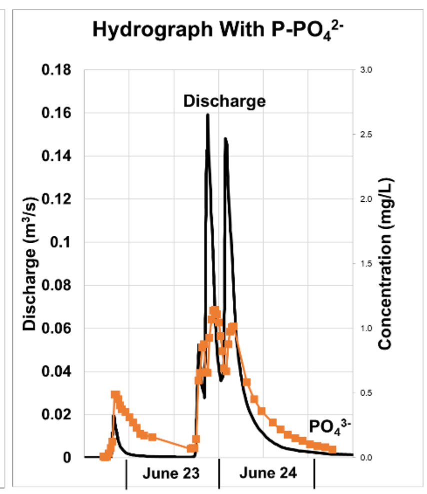

__Fig 3.__ Discharge hydrograph and PO_4^{3-} concentration during Tropical Storm Cindy.

7. NUTRIENT EXPORT FROM A PROXIMAL, INTERMITTANT STREAM DRAINING EKU MEADOWBROOK FARM, MADISON COUNTY, KY

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Agricultural activities contribute significant amounts of nutrients that contaminate surface and subsurface water. Eastern Kentucky University (EKU) Meadowbrook Farm (Madison County, Kentucky) seeks to decrease its export of nutrients to Muddy Creek using sequestration techniques. The first step in the overall process is to determine nutrient export at present, before sequestration efforts take place. Here we estimate the export of phosphate, nitrate, and ammonium during Tropical Storm Cindy (July 22 to 24, 2017) from a proximal, intermittent stream, named the BRC. This stream drains a representative portion the Farm, receiving water from a dairy complex, pasture, and cropland.

To estimate nutrient export, both discharge and nutrient concentration must be determined. We have built a V-notched weir across the BRC drainage equipped with a datalogger that measures water elevation behind the dam, and an autosampler that captures water samples during rain events. Water level and discharge over the dam are proportional, so that discharge can be calculated during rain events. Nutrient concentration is measured for each water sample using accepted colorimetric methods: ascorbic acid (phosphate), cadmium reduction (nitrate), and sodium hypochlorite (ammonium).

Once discharge and nutrient concentrations are measured for the rain event, total nutrient mass can be calculated from the resultant curves (Fig. 1). Discharge and concentration data were parsed into 30-second time steps over the course of the entire, 72-hour rain event, and we used a cubic spline application (grafted into *MS Excel*) to produce a continuous function for each parameter. The area under the discharge and concentration curves yielded total solute mass for the Cindy event.

Based on these data and using the cubic spline technique, we estimate that the export of phosphorus was 3.1 kg P occurring as dissolved orthophosphate, and 6.3 kg N occurring as dissolved nitrate (5.3 kg) and ammonium (1.0 kg) during Cindy. We also intend to determine the amount of total phosphorus (orthophosphate, other forms of dissolved phosphorus, P contained within dissolved organics, and P adsorbed onto fine particulates) exported during Cindy, as well as estimating nutrient export for five other rain events captured during 2017.

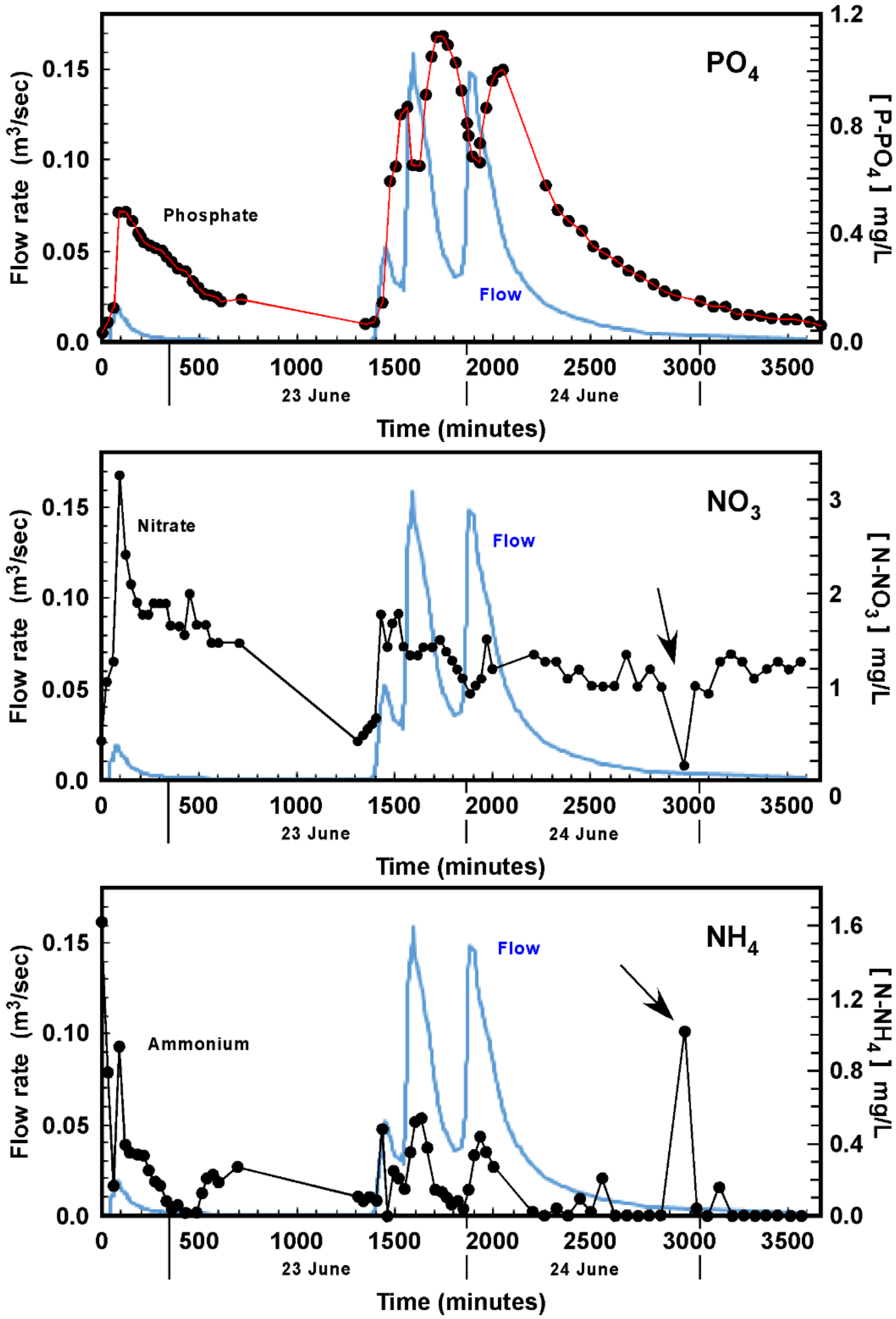

Fig 1. Graphs of water flow and nutrient concentration during Tropical Storm Cindy. These data were used to make export estimates for each dissolved nutrient during the rain event.

8. SPATIAL CHARACTERIZATION OF SOIL SATURATED AND NEAR-SATURATED HYDRAULIC CONDUCTIVITY AT THE FIELD SCALE

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Saturated and near-saturated hydraulic conductivity are important for assessing soil water movement and studying the effects of soil macro-pores on water flow. An accurate spatial characterization of wet-range hydraulic conductivity is therefore important for field water management. The interpolation of spatial data is generally performed with geostatistical methods (e.g., kriging and cokriging). Hydraulic conductivity data is usually limited since its measurement is time consuming and expensive. Cokriging, which estimates a variable that is under-sampled by considering its spatial correlation with an auxiliary variable that is more densely sampled, is usually more effective than kriging in estimating hydraulic conductivity. Therefore, the objective of this study was to characterize the spatial variability of wet-range hydraulic conductivity at a farmer's field with co-regionalization analysis.

Undisturbed soil cores were collected from surface soil (7~13 cm) at 48 locations with a distance of 100×50 m in a farmer's field in Princeton, Kentucky for measuring hydraulic conductivity. Saturated hydraulic conductivity was measured with a lab-permeameter based on Darcy's law. Near-saturated (h= -1 cm, h= -5 cm, and h= -10 cm) hydraulic conductivity was measured with a double plate pressure-membrane apparatus based on Buckingham-Darcy's law. Soil apparent electrical conductivity, which was used as an auxiliary variable to estimate hydraulic conductivity at a fine spatial resolution, was measured using a contact sensor Veris 3150. The interpolation of spatial data was performed by cokriging. Leave-one-out cross-validation was used to evaluate the accuracy of interpolation. Our study indicates that hydraulic conductivity and apparent electrical conductivity are spatially correlated. Saturated hydraulic conductivity exhibits strong spatial variability and macro-pores greatly influence soil water flow in the field.

9. SOIL PROPERTIES OF FARMS IN MARION COUNTY, KY

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Soil management practices are factors that affect soil quality. A soil that is subject to intense management has been shown to be more susceptible to erosion than soils subjected to no-till practices. Many farmers, however, still believe that at least some amount of plowing is necessary to increase aeration and allow easier access to nutrients by plant roots. The purpose of this research is to compare soils from farms under different management systems in Marion County, Kentucky. Samples will be collected from a conventional tillage plot, a no-till plot, a pasture used for grazing, and a wooded plot. Measures of soil organic matter, soil pH, soil water content, soil water holding capacity, and soil water content at field capacity have been collected. Analysis and interpretation of the data will be discussed in the poster.

10. USING ANTHROPOGENIC COMPOUNDS IN SEWAGE TO CREATE NEW FECAL SOURCE AND FECAL AGE INDICATORS FOR USE IN PROTECTING AND IMPROVING WATER QUALITY IN KENTUCKY

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In recent years, it has become apparent that established methods of fecal source tracking have their limitations. Some non-microbial methods have become obsolete due to the ubiquitous nature of some chemicals in the environment. Others, such as fecal coliform bacteria or PCR for bacterial gene sequences tend to be quite nonspecific and expensive. All of these methods have one thing in common; they cannot estimate the age of fecal materials like sewage. The lack of fecal age in these methods makes it hard to trace that pollution back to the point source. Many of the waterways we pollute feed into reservoirs used as drinking water sources. The Kentucky River supplies drinking water to 16% of the population of Kentucky; that is 710,000 people. The people in this watershed need to have ways to pinpoint areas for remediation to improve the quality of this vital water supply. As human impacts on surface waters continue to grow, an inexpensive, accurate method of fecal source tracking that has the ability to pinpoint where exactly fecal pollution is entering the environment is needed now more than ever.

The Environmental Research Training Laboratory, under the direction of Dr. Gail Brion designed a study to track Sucralose and acetaminophen through the wastewater treatment process. Samples of raw influent, pre-chlorination effluent, and post treatment effluent were taken during March 2016, February 2017, and June 2017 from Town Branch and West Hickman Wastewater Treatment Plants (WWTPs) in Lexington. Taking samples from both plants allowed for sucralose and acetaminophen levels to be compared across multiple facilities, and across their similar treatment processes. After looking at the preliminary data it is clear that both sucralose and acetaminophen are consistently present in WWTP influent (Table 1).

Site	Type	n	Acet (ng/mL)	Suc (ng/mL)	n	Acet/Suc Ratio	Std. Dev.
TB	RAW	15	80.8	40.2	15	2.50	0.88
	ST	8	<0.1	46.8		95% CI	4.04
	PTE	15	<0.1	43.5			0.95
WH	RAW	11	122.4	48.0	11	2.60	0.54
	ST	7	0.8	45.9		95% CI	3.58
	PTE	11	0.3	48.0			1.62

Table 1: Summary and combined data of WWTP studies.

Sucralose exits the plant in virtually unchanged concentrations whereas acetaminophen disappears below detection limits. Microbial decay of acetaminophen has been found to be significant, so the decrease across the activated sludge process is expected. It was also found that the ratio of sucralose to acetaminophen entering the two plants was not significantly different between plants, or over time (Table 1). Therefore, this ratio could be used to differentiate untreated from treated sewage in the environment, if more is known about the decay rate under environmental conditions.

Laboratory benchtop studies were done that simulated the natural rate of decay of acetaminophen relative to sucralose under different environmental conditions. Basically, either sewage influent or natural creek waters were spiked with acetaminophen and sucralose (if needed), held at a steady temperature in a batch system, with samples taken at different times throughout the 7 days of study. The kinetic decay studies were conducted at 21°C in March 2016 using WWTP influent, and again in June 2017 using spiked creek water. Cold weather studies were done at 4°C in February 2017 using WWTP influent and June 2017 using spiked creek water. It was found that the decay rate followed first order kinetics (Table 2) with slower decay rates at lower temperatures. It took about 48 hours for acetaminophen in sewage to decay below detection limits at 21°C. In creek water, acetaminophen took k92 hours to decay below detection limits at 4°C. Interestingly, inactivation of acetaminophen was not primarily linked to photo-inactivation, as the WWTP experiments were both done with only laboratory lighting and the creek water experiments were done in the absence of light (inside a refrigerator).

Simulated Decay Study Equations		
May 2016 21°C WWTP Influent	$y = -0.0596x + 2.9433$	$R^2 = 0.9778$
February 2017 4°C WWTP Influent	$y = -0.005x + 2.0296$	$R^2 = 0.99021$
June 2017 21°C Creek Water	$y = -0.0351x + 3.345$	$R^2 = 0.97767$
June 2017 4°C Creek Water	$y = -0.0009x + 2.2396$	$R^2 = 0.30654$

Table 2: Equations and R^2 values of the simulated decay studies of the Acet/Suc Ratio. Y is the predicted ratio and x is the time in hours since entering the environment.

Knowing that sucralose would be in samples that had received either treated, or raw sewage, a survey sampling of creek water throughout the Lexington area was done in April and July of 2017 to see what the values of sucralose were, and if the presence of acetaminophen might show reaches with fresher fecal signals. It was found that an average of about 0.2 ng/mL sucralose was present in creeks with a range of 0 ng/mL in a pristine setting to 0.408 ng/mL in an urban area. The maximum recorded sucralose concentration in creeks was more than 100 times less than found in sewage influent.

This approach using human specific chemicals that decay at very different rates needs to be expanded to look at other watersheds and other WWTPs to determine whether the ratio of these two human sourced personal care products can be used to reliably pinpoint sewage leaks. However, the preliminary results are promising and others in the field should evaluate if this approach can help them understand their watersheds and improve surface water quality for their communities.

11. BLUE WATER FARMS: EDGE-OF-FIELD MONITORING OF NUTRIENT AND SEDIMENT LOSS FROM WETLAND WATERSHEDS IN THE NORTHERN MISSISSIPPI EMBAYMENT

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Researchers from the University of Kentucky College of Agriculture, Food and Environment, and the Kentucky Geological Survey are partnering with the U.S. Department of Agriculture Natural Resources Conservation Service to conduct a wetland edge-of-field monitoring program, formally named Blue Water Farms. The goal of this program is to evaluate the effectiveness of conservation practices related to nutrient and sediment losses from agriculture row-crop fields converted to wetlands in the northern Mississippi Embayment. Rain generated surface runoff samples will be collected from six small (< 10 acre) wetland watersheds identified using LIDAR. The watersheds will be in one of three stages of wetland vegetative growth; 1) final soybean crop and tree planting, 2) intermediate herbaceous growth approximately 5 to 7 years after tree planting, and 3) mature timber stand. The outlet of each watershed will be instrumented with a flume, an ultrasonic flow meter, an automated composite water sampler, and a rain gauge. Water samples collected from each runoff generating precipitation event will be analyzed for nutrients (ammonium, nitrate, total Kjeldahl nitrogen, orthophosphate, and total phosphorus) and total suspended solids at the University of Kentucky Lexington campus. In addition, surface water discharge and precipitation measurements will be recorded. Fifty-four months of runoff data will be collected. The surface water quality and quantity data from these wetland watersheds will aid in determining the effectiveness of wetland conservation practices on nutrient and sediment losses in the northern Mississippi Embayment.

12. BLUE WATER FARMS: EDGE-OF-FIELD MONITORING OF NUTRIENT AND SEDIMENT LOSS FROM NO-TILL CORN AND SOYBEAN FIELDS IN THE LOWER GREEN RIVER WATERSHED

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Researchers from the University of Kentucky College of Agriculture, Food and Environment, and the Kentucky Geological Survey are partnering with the U.S. Department of Agriculture Natural Resources Conservation Service, Kentucky Soybean Promotion Board and western Kentucky row-crop producers to conduct an edge-of-field monitoring program, formally named Blue Water Farms. The goal of Blue Water Farms is to evaluate the effectiveness of conservation practices related to nutrient and sediment losses from active agriculture row-crop fields in the lower Green River basin. Runoff from no-till corn/soybean fields will be sampled for nutrients (ammonium, nitrate and nitrite, total Kjeldahl nitrogen, orthophosphate, and total phosphorus) and total suspended solids. In addition, surface water discharge and precipitation measurements will be recorded. Data will be collected between 8 and 10 years, which will include two years of baseline data and 6 to 8 years of control/treatment data. The control conservation practice is broadcast poultry litter and the treatment is poultry litter injection. Data collected from paired field-scale watersheds will aid in determining the effectiveness of surface amendment of litter to the injection of litter on nutrient and sediment loss in western Kentucky.

Six paired watersheds in two no-till corn/soybean rotation fields have been identified in the lower Green River basin. LIDAR and survey data were used to subdivide the fields into three control watersheds and three treatment watersheds ranging in size from 4, 5 and 10 acres. We anticipate that in the spring of 2018, six monitoring stations will be instrumented with a flume, an ultrasonic flow meter, an automated composite water sampler, and a rain gauge. We anticipate baseline sample collection will begin shortly after the stations are instrumented in late winter 2018. Nutrient and sediment samples will be analyzed at the University of Kentucky Lexington campus.

In fall 2018, we anticipate Blue Water Farms to expand with 12 additional watershed monitoring stations: six in no-till, corn-soybean rotation, tile-drained fields in the lower Green River watershed, and six in the Pennyrile focusing on cover crop best management practices. These sites will be instrumented, sampled and analyzed using the same protocol described above.

13. EDGE-OF-FIELD MODELING TO QUANTIFY THE CONTRIBUTION OF MACROPORE FLOW INTO NITROGEN LOADING FOR POORLY DRAINED AGRICULTURAL FIELDS

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Farmers have extensively utilized artificial drainage systems to drain excess water from agricultural fields to enhance crop yield. Tile drainage system consists of a network of perforated plastic pipes, typically 60 to 120 cm below the surface, to direct the drained flow into a pond or surface water channel. The implementation of tile drainage systems across the midwestern US have been reported to be a significant exporter of nutrients to the Western Lake Erie Basin and Gulf of Mexico. The USDA-ARS has established a series of edge-of-field (EOF) monitoring stations on privately owned farmlands to collect water samples from the surface and subsurface of agricultural fields. In the planning level, computer models can be utilized as powerful tools to simulate the surface and subsurface hydrology and water quality and subsequently inform recommendations for BMPs. In this work, the Agricultural Policy Environmental eXtender (APEX) 1501, and a modified version which simulates macropore flow, will be applied to an artificially drained field. Previous application of the macropore model focused on quantifying the impact of macropore flow on dissolved reactive P loads in tile and highlighted improvement of hydrologic and dissolved phosphorus simulations. In this study, we will modify the nitrogen routine of the model to examine how macropores are transporting dissolved nitrogen (DN) to stream channel. We expect the results to show that the effluent from subsurface through macropores is one of the major fluxes of DN loading into waterbodies. We will also compare the results of the two models to examine how the modified model improves the simulation capability of DN into tile. The modified model can be used to conduct scenario analysis for water quality management purposes.

14. HIGH RESOLUTION SENSING OF NITROGEN DYNAMICS IN A MIXED-USE APPALACHIAN WATERSHED: INFLUENCES OF A BACKWATER RIPARIAN WETLAND

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Harmful algal bloom proliferation occurring on the Ohio River has generated a renewed interest in nutrient fluxes from Appalachian watersheds. Headwaters of these watersheds often drain steep-gradient hillslopes; however, discharge to the Ohio River occurs in lowland valleys, producing seasonally inundated stream-wetlands. Tributary perirheic mixing with the main-stem, stream hyporheic mixing with a seasonably varied groundwater table, and variable upland concentrations from dynamic source contributions, creates a highly variable nutrient signal, difficult to characterize using traditional monitoring techniques. These watersheds currently lack water quality monitoring infrastructure that can capture these high resolution dynamics. The goal of this study is nutrient dynamic quantification within these wetland landscapes using novel sensing platforms. The site under study is the Fourpole Creek watershed ($60km^2$) draining predominantly forested, urban, and agricultural landscape through a palustrine forested wetland ($0.14km^2$) in West Virginia. Data will be analyzed for the stream-wetland system monitored at the downstream boundary for turbidity, conductivity, pH, dissolved oxygen, fDOM, temperature, flow, and dissolved nitrate/nitrite at 15-minute intervals using a state-of-the-art water quality monitoring platform. Sediment trap samples were collected weekly at upstream and downstream locations for a year, and analyzed for elemental and isotopic compositions. With the aid of this continuous data, results of total nitrogen load estimates, including dissolved and particulate nitrogen, at event to seasonal timescales will be quantified using modeling estimates of flow in a non-uniform and unsteady system. Additionally, we will perform sampling routine scenario analysis to compare traditional grab sampling routines to high-res sensing of Appalachian forested watersheds. Preliminary sensor data results collected at the watershed outlet highlights a noisy timeseries for all parameters that reflect fluctuating contributions from the Ohio River and Fourpole Creek. During stormflows, Fourpole Creek signatures are found to be dominant, highlighting broad fluctuations in dissolved nitrogen and sediment flux parameters over short time-intervals. Elemental measurements from sediment traps display seasonal fluctuations in sediment entering the wetland that is not found at the watershed outlet, suggesting attenuation and transformation of sediment nitrogen within the wetland. Ultimately, this data will be used to inform hydrologic and water quality models that quantify fluxes and apply them for management/scenario analysis.

15. CLIMATE CHANGE IMPACTS ON SEDIMENT TRANSPORT IN KENTUCKY: SENSOR VALIDATION, CONTROLLING PROCESSES, AND FUTURE PROJECTIONS

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The results of global circulation models indicate that the future climate will likely have a substantial effect on hydrological processes of the watershed. However, the literature still has lack of understanding of how climate change will affect the sediment processes in the watershed system. The authors hypothesized that variations in mean and extreme changes, in turn, might impact sediments in depositional and erosional dominance in a manner that may not be obvious to the watershed manager. We, therefore, investigate the inner processes connecting the combined effect of extreme climate change projections on the upland erosion and instream processes to produce changes in sediment redistribution within a lowland watershed system.

The research methods are proposed based upon simulating sediment processes in forecast and hindcast periods. Publicly available climate realizations from several climate factors and the Soil Water Assessment Tool were used to predict hydrologic conditions for the South Elkhorn Watershed in central Kentucky, USA in 2050. The results of the simulated extreme and mean hydrological components are used in simulating upland erosion with the connectivity processes consideration and thereafter used in building the instream erosion and deposition of sediment processes model with the consideration of surface fine grain lamina layer. A new automated sensors platform is being used for numerical model calibration and validation.

Results of climate change impact on the sediment yield suggest that the average annual sediment yield will likely increase when considering the 11% and the 49% increases in the average annual streamflow and in the 100 year event, respectively. A new result unique to our work is the suggestion made by the model that the climate change will likely cause an increase in the deposition to the SFGL in a stream of lowland watersheds. Ongoing research is investigating climate change impacts on longitudinal and lateral sediment connectivity processes.

16. WATER SUPPLY IMPACTED BY ALGAE AND SEDIMENTATION IN KENTUCKY: ADVANCING SENSORS AND NONCONSERVATIVE TRACERS

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Water supply can potentially be impacted by sedimentation and the production of toxic algal blooms. Watershed sedimentation can fill reservoirs reducing their water storage capacity. Excessive nutrient pollution can cause eutrophication within water bodies promoting the growth of algae. Cyanobacteria concomitant with toxic algal blooms can release cyanotoxins that damage fresh water ecosystems and threaten water supply by creating hypoic dead zones.

Sediment and nutrient tracer-based fingerprinting coupled with high resolution sensing serves as a means to allocate source contributions of loads and quantify transport rates to reservoirs. However, tracers, and specifically stable isotope tracers, have the potential for being nonconservative, and the fate of the potential tracers requires quantification to justify their usefulness. Further, rarely, if ever, have researchers discriminated in-stream and upland sources from the fate and transport processes using nonconservative tracers and high resolution sensors.

This study was motivated by the need to identify sediment and nutrient sources at the catchment scale to inform watershed erosion and sediment transport models that rely on sensor technology to assess sediment's threat on water supply. The objectives of this study include: (1) investigating the fate and transport of sediment and nutrients in a lowland catchment accounting for the nonconservative nature of biogeochemical tracers, (2) testing new isotope tracers coupled with sensor data streams and sediment connectivity numerical modeling to improve transport models and flux calculations, and (3) analyzing organic carbon and nutrient fate in relationship to stream processes in an experiment to examine mineralization and isotope fractionation.

Lowland stream networks were focused upon in this study due to their efficiency to store sediments that assimilate nutrients due to their low-gradient nature. Moderate and high flows in lowland catchments transport a heterogeneous mixture of upland, bank, and, streambed fine particulate organic matter from autochthonous and terrestrial sources. Additionally, the study lowland watershed's significant occurrence of fine sediment storage in the streambed promotes chemical bonding of nutrients due to the cohesive nature of fine sediment.

Sediments were analyzed for carbon and nitrogen content, applying stable isotopic ($\delta^{13}C$, $\delta^{15}N$) compositions. These biogeochemical tracers associate with plant cover, land-use, and land management at the sediment sources, including upland and bed sediments. Organic tracers tend to discriminate sediment sources through differences in soil organic matter cycling, the biogeochemical process by which sediments form their organic signature. A combination of field data collection, laboratory analyses of sediments, and statistical modeling techniques provides a method to distribute applicable tracers to sediment sources within the watershed. The alteration of carbon and nitrogen isotopic compositions during transport were studied in both oxic and anoxic conditions. Once changes during transport occurring to the sediment and tracers are accounted for, the contribution of fluvial sediments from each source can be estimated by coupling with a mass balance un-mixing model.

17. COUPLED HYDRAULIC AND SEDIMENT TRANSPORT MODELING OF A FLUVIAL KARST AQUIFER IN THE BLUEGRASS REGION OF KENTUCKY

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Karst landscapes are solutionally dissolved leading to the development of secondary and tertiary porosity pathways and complex hydraulic, sediment, and nutrient transport dynamics. Although advances in the understanding of transport dynamics in karst have been made, modeling efforts remain insufficient when considering mature surface-subsurface networks. Mature karst systems are characterized by a highly-coupled surface watershed and groundwater basin, a mature soil-covered epikarst, a developed fracture and fissure network, and a primary phreatic conduit that discharges flow to a main spring. The objective of this study was to develop a comprehensive hydraulic, sediment, and nutrient transport model that can be applied to and effectively simulate mature karst systems.

The hydraulic model simultaneously solves conservation of mass, momentum, and energy equations and is comprised of three sub-routines: a hydrologic diffuse flow model, a stream routing model, and a conduit pipe network model. Data inputs to the model include climate, land use, topography, surface tributary sediment concentrations, and conduit bathymetry. The fate and transport of sediment carbon and nitrogen is considered in the model and the stable isotope signatures of carbon-13 and nitrogen-15 are used to constrain model parameterization. To calibrate the sediment model, high frequency turbidity measurements were recorded and TSS samples were collected every seven hours at the spring outlet during the summer of 2017. The model was applied to the coupled Cane Run Creek Watershed and Royal Springs Groundwater Basin located in Fayette and Scott Counties, Kentucky. Royal Springs is the pour point of the groundwater basin and is the drinking water source for Georgetown, Kentucky.

Current manually calibrated hydraulic model results for an event in April 2016 has a Nash-Sutcliffe Efficiency rating of 0.93, which indicates that the model preforms well and captures the dynamics of the system. It is anticipated that complete multi-year hydraulic, sediment, and nutrient transport model results will have high performance ratings and improve upon existing models in the same watershed. The results of this study should provide researchers and practitioners a new modeling tool that can be effectively applied to fluvial karst aquifer with flow dominated by a phreatic conduit and has high connectivity to a surface stream. Also, results of this model should further knowledge of hydraulic, sediment, and nutrient dynamics in karst.

18. TEMPORAL VARIATIONS OF HIGH RESOLUTION NUTRIENT CONCENTRATIONS IN MATURE VS IMMATURE KARSTIC WATERSHEDS

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Study of the temporal variations in nutrient concentrations has been limited in the past in terms of the temporal resolution of samples taken. This is primarily due to the time and man-power constraints that exist when conducting grab-sampling regiments in the field. The recent advancements in continuous, *in-situ* nutrient sensors have therefore made high-resolution, high-quality nutrient sampling increasingly possible. The relatively few studies that have been conducted in the United States using such sensors have generally been conducted on very large watersheds, such as the Mississippi River Basin, Columbia River Basin, and the Potomac River Basin. Rarely have such studies been conducted in smaller watersheds such as the South Elkhorn and Cane Run sub-basins ($< 75\ km^2$), and very rarely have such sensors been used to monitor nutrient levels in mature karst dominated watersheds. The current objective of this study is to use continuous, high-resolution *in-situ* nutrient sensors to monitor the temporal patterns and variations of nutrient concentrations (specifically of nitrogen, most commonly found in natural streams as dissolved nitrate, NO_3^-) in the streams and to analyze the effects of mature vs. immature karst landscape features on the resulting concentrations in similar watersheds.

Nutrient monitoring “platforms”, consisting of the SeaBird-Coastal SUNA V2 nitrate sensor, the SeaBird-Coastal HydroCycle-PO4 phosphate sensor, and various Yellow Springs, Inc. 6-Series Water Quality Sondes (measuring temperature, turbidity, conductivity, dissolved-oxygen, and pH) have been deployed in two watersheds in central Kentucky. The South Elkhorn watershed is a 62 km^2 basin near Lexington, KY and has been defined as a surface-flow dominated, immature karst watershed. The Cane Run watershed is a 98 km^2 basin near Georgetown, KY with a 58 km^2 area made up of a coupled surface-subsurface network. This watershed has been defined as a mature karst watershed with flow occurring both in the surface stream and a sub-surface conduit fed by an extensive series of sink- and swallet-holes in the watershed surface. Data from these “platforms” has been compared using various time-series analysis techniques. Additionally, data for identical parameters, made available by the U.S. Geological Survey, was included in the comparison and analysis of the effects of mature vs. immature karst landscapes for larger watersheds in Kentucky; including the Licking River in northeast Kentucky, the Green River in south-central Kentucky.

Preliminary time-series data analysis has resulted in the identification of pronounced patterns and variations in nitrate concentration diurnally; as well as proceeding, during, and after large hydrologic events. Average nitrate concentrations in karstic systems have been found to be significantly higher consistently compared to average concentrations in surface-water dominated systems. A specific pattern has been identified during hydrologic events for both mature and immature karstic systems. As the hydrograph for the watershed rises, the nutrient concentrations will generally fall drastically, and then begin to rise again as the hydrograph peaks and begins to fall. Concentrations will generally peak sometime after the hydrograph. This “lagging” concentration peak is assumed to be a function of several factors; including watershed land-use and soil characteristics, hydrologic event magnitude, weather and climate conditions, etc. With an expanding dataset, further analysis and modelling is planned to more comprehensively investigate these phenomena. For example, analyses of hysteresis loops, pre-vs post-extreme events, hydrograph separation, and nutrient decay modeling are ongoing. Relevant findings from this study will help to further understand the nutrient processes in karstic systems and how they compare to surface streams. More specifically, the use of continuous, *in-situ* nutrient sensors in karst systems will help to elucidate the previously understudied field of sub-surface nutrient dynamics.

19. SYNTHESIS OF BIOLOGICALLY-INSPIRED NANOFILTRATION MEMBRANES USING PROTECTED AND MUTATED AQUAPORINS

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Aquaporins are protein water channels present in cells, and they restrict the passage of contaminants and small molecules such as urea and boric acid, without preventing the passage of water. Biomimetic water treatment polymeric membranes attempt to replicate this natural process of high selectivity and efficient transport of different molecules by embedding the polymeric membrane with aquaporins. Therefore, aquaporins have received worldwide attention because of their potential to form biomimetic membranes with high flux and selectivity for water treatment. However, challenges involved in the incorporation of aquaporin proteins in membranes limit their applicability. One of them is to attach aquaporins to the membranes without chemically altering or damaging the aquaporins during the binding to the membrane. The second challenge is to design and prepare an assembly that allows biomimetic membranes with aquaporins to sustain hydraulic water pressure gradients without losing their integrity and performance. The overarching objective of this project was to form a biomimetic membrane made of unaltered aquaporins dispersed in a polymeric membrane selective layer and capable of operation under high hydraulic pressure. Membranes modified with mutated aquaporins showed higher and consistent rejection values for increasing feed concentrations, higher flux recovery and lower flux declines.